Automotive Composites – Challenges and UK Position

Dr Faye Smith, Composites UK Automotive Showcase, May 2015
Contents

- Global interest in automotive composites.
- Challenges.
- UK Automotive Industry.
- Where automotive composite development sits in the bigger UK Composite Strategy picture.
- Future work.

Note template style changes used to accredit providers/owners of information.
Global Interest in Automotive Composites
Driver for Use of Composites

The investigation of the use of composites in automotive applications is predominantly driven by a wish to reduce vehicle weight, which in itself is driven by factors including:

- Increasingly stringent greenhouse gas regulation (US CAFÉ 35.5mpg by 2016, EU 130kg/km CO\textsubscript{2} by 2015, 95kg/km by 2020).
- Increase in addition of systems and features that add weight to the car.
- Use of alternative powertrains and the need to extend range.

![Vehicle Weight by Generation](chart_image)

![Figure 2: Segment average kerb weights 1990 - 2012 (Europe)](chart_image)
Growth, but at what rate?

- As we will see, there are many challenges to be faced to effect the successful introduction of composites (CFRP) into volume automotive production. Therefore publicly available growth figures for the use of composites specifically for the automotive sector vary, but all predict significant growth with just three examples being:
  - Lucintel predicts the global market for composite materials in the transportation sector will reach $8.6bn in 2020 and have a CAGR (2014-19) of 6.5%.
  - In the automotive sector, [CFRP] revenues are expected to grow by 7% annually until 2018. By 2022, annual global carbon composite revenues are forecast to reach US$4.9B (€4.21B). [SusChem Position Paper, Jan 2015].
  - According to the Frost & Sullivan report Supply Chain Analysis of the Automotive Carbon Fiber Composites Market, the automotive carbon fibre composites market is likely to grow to US$95.5 million by 2017 at a compound annual growth rate (CAGR) of 30.6%. [Reinforced Plastics 2012].
Collaboration in CFRP production

- Most automotive OEMs are collaborating with carbon fibre suppliers and/or moulders to investigate the use of carbon fibre composite parts
  - BMW and SGL Group
  - General Motors and Teijin
  - MAGNA and Zoltek (owned by Toray)
  - Ford and Dow
  - JLR and Cytec
  - Toyota, Nissan, Subaru and Honda with Toray, Mitsubishi Rayon & Toho Tenax

The biggest story so far - BMW i3
Challenges Faced

- Rocky Mountain Institute work.
- Carbon fibre perspective, which the main focus is on, but can be applied to most composites.
Raw Material Cost

- Automotive targets $4 - $7/lb (£6 – 9/kg), tensile 250 ksi, 25 Msi, 1% ultimate strain

Costs savings can also be made by scale up.

[University of Manchester]
Much work is being done by OEMs and composite moulders to figure out what production technologies will be cost effective for which production rates.

Niche vehicle manufacturers (say up to 5000 parts per year) will be able to tolerate slightly higher cycle times (& dare we say it, cost) than mid-range producers (say up to 50,000 ppy) and mid range will tolerate more than high volume producers (million(s) ppy). So they will favour different processes. These windows of affordability have not yet been determined.

Whatever process they use automation will be key!
As always with composites, the material used is dependent on both the properties required and the production process used.

Therefore cycle time requirement and choice of production process can have a double hit on end cost by also increasing material cost.
LCA and Recycling

- Environmental awareness = Life Cycle Analysis comparison required (use of bio-based materials?).
- Current (ELV = 95%) and potential future recycling targets mean a new approach to end of life – development of new recycling and reuse supply chain capability.

Table 18: DoE US targets and metrics for carbon fibre and composites

<table>
<thead>
<tr>
<th>Metric</th>
<th>Baseline</th>
<th>2025</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilization</td>
<td>Limited-to-no use</td>
<td>5% of vehicle mass</td>
<td>15%-25% of vehicle mass</td>
</tr>
<tr>
<td>Cost</td>
<td>Fiber: 5$/lb</td>
<td>Fiber: 3$/lb (stretch goal)</td>
<td>Fiber: 3$/lb (stretch goal)</td>
</tr>
<tr>
<td>Fuel-Based Cost Tolerance $/lb. saved</td>
<td>Base</td>
<td>$3.42/lbs. saved*</td>
<td>$4.32/lbs. saved*</td>
</tr>
<tr>
<td>Modeling</td>
<td>Limited</td>
<td>Design with 50% theoretical CF limits</td>
<td>Design with 75% theoretical CF limits</td>
</tr>
<tr>
<td>Design</td>
<td>-</td>
<td>50% of theoretical limits</td>
<td>Design with 75% theoretical CF limits</td>
</tr>
<tr>
<td>Raw Materials</td>
<td>Fibers: polycyanoitrile</td>
<td>Non-petroleum based materials (precursors, fibers, resins)</td>
<td>100% recyclable materials</td>
</tr>
<tr>
<td>Manufacturing Cycle Times for CFCs</td>
<td>&gt; 5 minute</td>
<td>&lt; 3 minute</td>
<td>&lt;1 minute</td>
</tr>
<tr>
<td>Joining</td>
<td>-</td>
<td>Joining technology for CF-CF and CF-metal at cost and time - steel design</td>
<td>-</td>
</tr>
<tr>
<td>Recycling</td>
<td>-</td>
<td>100% recycled</td>
<td>100% recycled</td>
</tr>
<tr>
<td>Repair</td>
<td>0% detection</td>
<td>100% detection</td>
<td>100% detection</td>
</tr>
</tbody>
</table>

IHS Automotive 2014

TARF – LCV, EPSRC project
The generic need to increase the knowledge base in automotive OEMs with regard to composite design, production and end of life is generally well recognised and the links with carbon fibre suppliers and moulders is a good way to speed this up.

However one of the bigger questions is how the introduction will be managed.

- The best way to design with composites is to start from scratch (i.e. not black metal) that way you can benefit from reduced number of parts and use appropriate materials where required. However complete redesign of an entire automotive production line is a big step to take.

- The alternative – introduction of composite parts into an existing supply chain - still represents a significant disruption to existing production lines as composites require different painting, joining methods etc. and you do not necessarily get the full benefit of use of composite (as above).
UK Automotive Industry
Over the past seven years the UK has emerged as one of the most globally attractive locations for Automotive investment. The foundations for this success have been based on three key areas;

1 - Growing Supply Chain Opportunity: The UK is experiencing an unprecedented period of growth in production volumes driven by global demand for UK-manufactured vehicles as well as a domestic market that is the fastest growing in Europe. This has resulted in a unique supply-chain opportunity.

2 - Transformational Research & Development: The UK provides an ecosystem which brings together leading-edge firms, universities, motorsports and funded projects to develop, commercialise and deliver technological innovations in the Automotive sector.

3 - Supportive Business Environment: The UK boasts one of the most progressive and flexible business environments which has made us number one in Europe for foreign direct investment.
UK Trade & Investment

Vehicle Plant Locations & Output 2014

Land Rover Halewood
Freelander 48,049
Evoque 126,707

Leyland Trucks
Leyland Trucks
Trucks 11,869

Alexander Dennis
Leyland
Lambert
Trucks 1,793

Nissan
Sunderland
Leaf 17,339
New Note 65,143
Juke 132,646
New Qashqai 285,110

Optare
Sherburn
Continental 9,765
Mulsanne 849

Bentley
Crewe
Continental 9,765
Mulsanne 849

Toyota
Burnaston
Auris 140,068
Avensis 32,147

Alexander Dennis
Larbert
Trucks 1,793

Leyland Trucks
Leyland
Trucks 11,869

General Motors
Ellesmere Port
Astra 77,836

Jaguar
Castle Bromwich
F Type 11,033
XF 45,119
XJ 16,712

GM
SAIC MG Motors
Birmingham
3,054

BMW
Mini
Oxford
Mini – 178,993

Rolls Royce
Goodwood
4,381

Others
Morgan – 464
Caterham – 461

Honda
Swindon
Jazz 23,964
Civic 43,815
CRV 54,020

Optare
Sherburn
Continental 9,765
Mulsanne 849

Land Rover
Solihull
Defender 7,727
Discovery 50,631
Range Rover 141,241

Dennis Eagle
Warwick
Trucks 741

Aston Martin
Gaydon
3,967

McLaren
Woking
1,751

Lotus
Hethel
1,492

Geely
(London Taxi Co)
Coventry
1,376

Toyata
Burnaston
Auris 140,068
Avensis 32,147

McLaren
Woking
1,751

Others
Morgan – 464
Caterham – 461

Hosho
Swindon
Jazz 23,964
Civic 43,815
CRV 54,020

Source: SMMT 2014
Projected Production Growth

Source: SMMT 2014
A growing supply chain opportunity: a £4bn commercial opportunity looking forward to 2018

• Currently around one third of the components in a UK-built car are domestically sourced, creating a continuing opportunity for UK supply chain investment.

• UK vehicle manufacturing is undergoing a renaissance – British car production is projected to be over 2m by 2018.

• Vehicle makers have input to the updated list of sourcing opportunities which total £4bn
UK Automotive Composites Interest

The work that the Automotive Council is doing with UK-based Automotive OEMs to ensure their UK supply chain increases, along with the huge growth in the market and the wish to increase the use of composites in cars means the number of composite moulders expressing an interest in developing applications in the UK is keeping UKTI very busy!
UK Composites Strategy and Automotive Composites
The CLF was formed as a result of the 2009 UK Composites Strategy to provide leadership.

The CLF is working to influence the Government and other bodies (including industry, research centres, academia, skills providers) to bring together support for composites and ensure growth and industrial success for the UK.

*Within the context of Government’s Plan for Growth and emerging industrial strategy.*
Consultation and strategy refresh

CLF Formation
Constitution and Purpose:
- Cross sector representation
- Industry report
- Establish CLF Working Groups

Working Groups
Consultation with industry sectors:
- Identify key issues and initial recommendations
- Align across Working Groups

Industry Consultation
Test Working Group outputs:
- Supply chain businesses
- Academia
- Supporting organisations

Develop Strategy
Analysis:
- Identify themes and actions
- Develop cross-sector approach
- Align support opportunities

Government Support
Identify funding and other support mechanisms:
- Already planned
- Necessary in future
- Industry priorities

Deliver Strategy
Oversight and alignment:
- 2015 strategy
- Monitor and influence delivery actions
- Refresh

Strategy documentation will be delivered later this year, in the meantime, CLF is getting on with seeking Govt support and delivering!
CLF Cross-Sector Strategy Development

Engage with Sector Strategies to understand opportunities and challenges for composites applications

- Aerospace
- Defence
- Automotive
- Rail
- Construction
- Marine
- Oil & Gas
- Renewables

Sector roadmaps – composites issues

Develop UK composites capability for multi-sector benefit

- Technology & Manufacturing
- Supply Chains
- Knowledge & Skills

Cross-sector, shared demands, common development actions

Composites Technology Roadmap
Part of the data analysis has included analysis of what composite products could or will be made in the UK to understand common technology and manufacturing requirements.....
The manufacturing clusters define similarities in production technologies, supply chain configurations, cost models and skills models. The strategy will define work to maintain or develop capability in these clusters and facilitate knowledge transfer within the clusters.
Composites Manufacturing Clusters

Common requirements between niche auto, defence and aerospace. UK needs to maintain World-class know-how.
Automotive sector has requirements in both high volume, low cost and mid volume, structural manufacturing. The UK needs to develop capability in both of these and this capability will provide benefits across multiple industry sectors.
Auto Roadmap – Technology Requirements

The following two slides show some of the output from the automotive roadmapping workshops in 2013/14. They are provided for information, although it should be recognised some of the thinking (especially in terms of production volume analysis) has moved on slightly.

<table>
<thead>
<tr>
<th>Technology Topics</th>
<th>Retention of niche manufacturing capability</th>
</tr>
</thead>
</table>
|                   | **Know-how and capability in volume production processes for components.**  
|                   | To include: Development of capability in processes such as TPs, HPRTM and stamping. Optimisation of materials and tooling used in the processes. Textile production. Generation of a database of materials and mechanical properties to facilitate design and specification of composites. Cost reduction of materials and processes. NDT. |
|                   | **Know-how and capability in volume production technologies for structures.**  
|                   | To include: Design for manufacture. Manufacturing simulation. Automation. Textile handling and drape simulation. Joining techniques at high volume and design for assembly and disassembly. |
|                   | **Recycling.**  
|                   | To include: End of life recycling and process waste recycling techniques. Use of recycled products to reduce the cost of production. Use of recycled products to ensure delivery of environmental targets. |
|                   | **Automotive Composite Structure Optimisation.**  
|                   | To include: Design for crash. Earthing and lightning protection (tech transfer from aerospace?). NVH optimisation. Volatile reduction. Repair techniques. |
# Production Volume Analysis

<table>
<thead>
<tr>
<th></th>
<th>Production Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UK current expertise</strong></td>
<td><strong>UK aim in next few years</strong></td>
</tr>
<tr>
<td>Niche volume</td>
<td>Higher Niche Volume</td>
</tr>
<tr>
<td><strong>Leapfrog?</strong></td>
<td>Mid volume</td>
</tr>
<tr>
<td><strong>Comments</strong></td>
<td></td>
</tr>
<tr>
<td>Payback time</td>
<td>3-5 years</td>
</tr>
<tr>
<td><strong>Tool material</strong></td>
<td>CFRP/PE</td>
</tr>
<tr>
<td></td>
<td>Aluminium</td>
</tr>
<tr>
<td><strong>Cycle time</strong></td>
<td>Days (many tools - part variation)</td>
</tr>
<tr>
<td></td>
<td>Hours</td>
</tr>
<tr>
<td></td>
<td>&lt; 5 minutes</td>
</tr>
<tr>
<td><strong>Cost of quality</strong></td>
<td>High (man hours finishing)</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td></td>
<td>Low (Minimal secondary processing, final quality off tool)</td>
</tr>
<tr>
<td><strong>Product &amp; Process Simulation</strong></td>
<td>Physical prototype &amp; testing</td>
</tr>
<tr>
<td></td>
<td>Materials, process and product simulation.</td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td>Skilled manual content, hand lay/pressure pot.</td>
</tr>
<tr>
<td></td>
<td>Some automation (e.g. cutting), use of preform, heating, e.g. processes HPRTM, infusion.</td>
</tr>
<tr>
<td></td>
<td>Full automation, minimal manual content.</td>
</tr>
<tr>
<td><strong>Labour/quality</strong></td>
<td>Labour intensive, quality dependent on high skill of labour.</td>
</tr>
<tr>
<td></td>
<td>Reduced labour, quality dependent on process .</td>
</tr>
<tr>
<td></td>
<td>Lights out, consistent high quality.</td>
</tr>
<tr>
<td><strong>Capex requirement</strong></td>
<td>£10k tooling (OEM own), £500,000 (if autoclave), £100,000 (non autoclave)</td>
</tr>
<tr>
<td></td>
<td>£250k tooling (recovered on part price), £millions for whole process.</td>
</tr>
<tr>
<td></td>
<td>£millions tooling. £50m for automated production facility.</td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td>Prepreg (€120/kg), mixed resin + fabric.</td>
</tr>
<tr>
<td></td>
<td>Resin (€40/kg) + fabric (€18/kg).</td>
</tr>
<tr>
<td></td>
<td>Base resin (€5/kg) + higher tow fabric.</td>
</tr>
<tr>
<td><strong>Design based waste</strong></td>
<td>Low</td>
</tr>
<tr>
<td><strong>Process waste</strong></td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Low (Minimal secondary processing, final quality off tool)</td>
</tr>
</tbody>
</table>
Future Work
The refresh of the CLF’s Composites Strategy will be formally published later this year.

In the meantime, work is ongoing to deliver it!

Here are two example relevant to automotive composite requirements.
The CLF is working with the Chemistry Growth Partnership (through the KTN’s Knowledge Centre for Materials Chemistry) through the Chemistry Subgroup of the CLF’s Technology Working Group.

The aims are to define the chemistry requirements within the Composites Strategy and define a programme of work to be discussed with funding bodies.

The following slide gives an overview of the themes being considered.

A workshop was held on 28th April to help define the R&D required within these themes.

A report will be delivered to the CLF and CGP in June.
Proposed R&D Themes

Virtual

- Multi-scale modelling & design of virtual composite materials.
  - Combining chemistry and thermodynamic approaches.
    - Looking at:
      • Initial properties
      • Through life
      • End of life/Sustainability
      • Processing
      • Multifunctionality
  - Possible stepping stone: Validated, integrated, empirical/theoretical framework for virtual testing of materials in a real world environment.

Physical

- Process Improvement.
  - Chemistry solutions to improve existing, or deliver new composite processing techniques.
- Property Improvement
  - Chemistry solutions to improve the mechanical properties and/or increase functionality of composites.
- Fibres
  - Chemistry solutions to optimise existing fibres (cost, properties etc) and develop new engineered reinforcement solutions.
- Sustainability
  - Chemistry solutions to facilitate recycling and replacement with sustainable materials.
- Characterisation
  - Methods of capture of data on molecules, materials, processes etc.
The Automotive Council’s Manufacturing Group and the CLF’s Technology Working Group are in discussion with funding bodies about a programme of work to develop UK capability in Affordable Composite Structures.

60 people from the Automotive Industry (incl. 8 OEMs) and Composite Supply Chain have been invited to a workshop on 4th June at NCC to following on from the roadmapping work done and map out this programme of work.